Successful Next Generation Low NO_X Burner Retrofit Project in a Northern California Refinery

Callidus Technologies LLC

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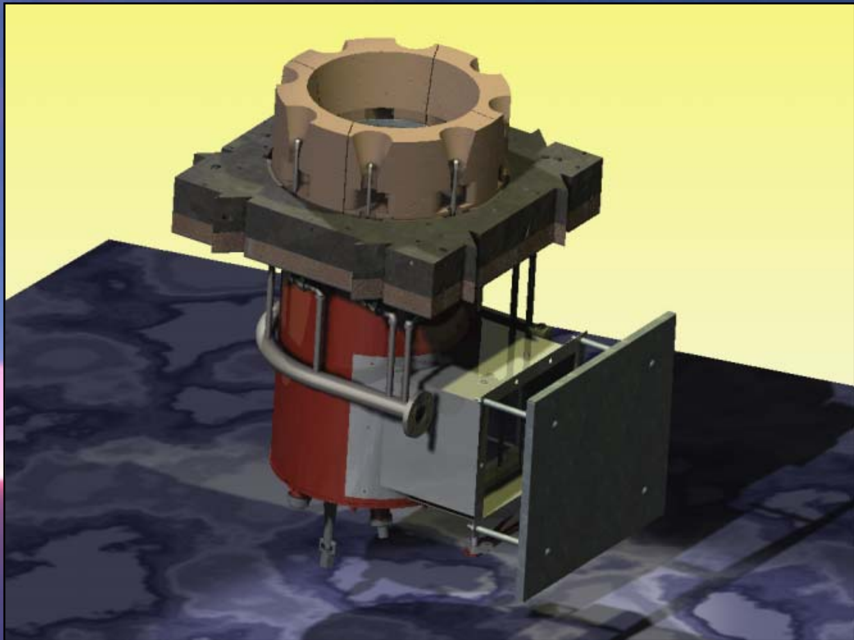
- Northern California Goals:
  - January 1994 Rules Laid Down: Meet 0.033 #/MMBtu
  - 50% of total fire duty by July 2000
  - 100% of total fire duty by July 2002
  - 8 year program
- Texas Goals:
  - December 2002 Rules Laid Down: Meet 0.25 to 0.36 #/MMBtu
  - 35% by April 2004
  - 60% by April 2005
  - 70% by April 2006
  - +80% by April 2007
  - 5 year program

Burner Retrofit is Part of a Facility Wide NO_X Reduction Project

- Technologies Typically Considered for Petrochemical NO_X Reduction Include:
  - Next Generation Low NO_X Burner Retrofits
  - Steam Injection
  - External Flue Gas Recirculation (Burner Retrofit?)
  - Selective Catalytic Reduction (SCR)
  - Most Plans Combine Technologies



Keys to a Successful NO_X Reduction Project

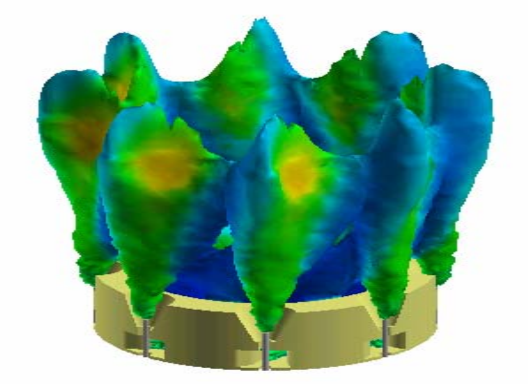
- Meets the Corporate Level Environmental and Production Long Range Operating Plan
- Is Delivered to Meet the Project Goals
  - On Time
  - On Budget
  - On Specification: NO_X Reduction Criteria w/o adversely affecting production
  - To the Satisfaction of the Customer (Operations)
- Planning is Required to Meet Goals
- Performance Review and Verification After Each Phase

The Plan for This Successful NO_X Reduction Project

- Planning: Outside Consultants Were Used to Target Heaters and Evaluate Technology Options.
- Specification: Achieve or Exceed an Average of 0.033 #/MMBTU (HHV) for All 30 Refinery Process Heaters and Boilers.
- Strategy: Select Heaters Having the Lowest Modification Cost Per Pound of NOX Removed. This Drives the Total Installed Cost of the Project to a Minimum and Provides "Most Bang for Your Buck."

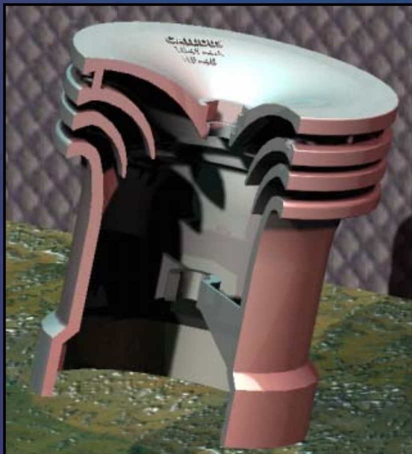
The Plan for This Successful NO_X Reduction Project

- Specification Testing: Install Next Generation Burners on Some Heaters Early In the Program to Verify Technology, Budget, NO_X Reduction Estimates and Reduce Risk.
  - Risk Management
    - Front Load Projects
    - Allow Time for Testing of Newest Technology
- Specification: Allow Additional Development Time and Adjust the Schedule Accordingly to Meet Certain Extremely Demanding Heater Applications.



The Plan for This Successful NO_X Reduction Project

- Budget and Schedule: Complete All Modifications During Already Scheduled Maintenance Turnarounds, or On-line.
- Customer Satisfaction: Select and Install Reliable Equipment, That Does Not Affect Unit Operations or Capacity
- Customer Satisfaction: Perform All Work With Zero OSHA Recordable Accidents or Environmental Incidents.

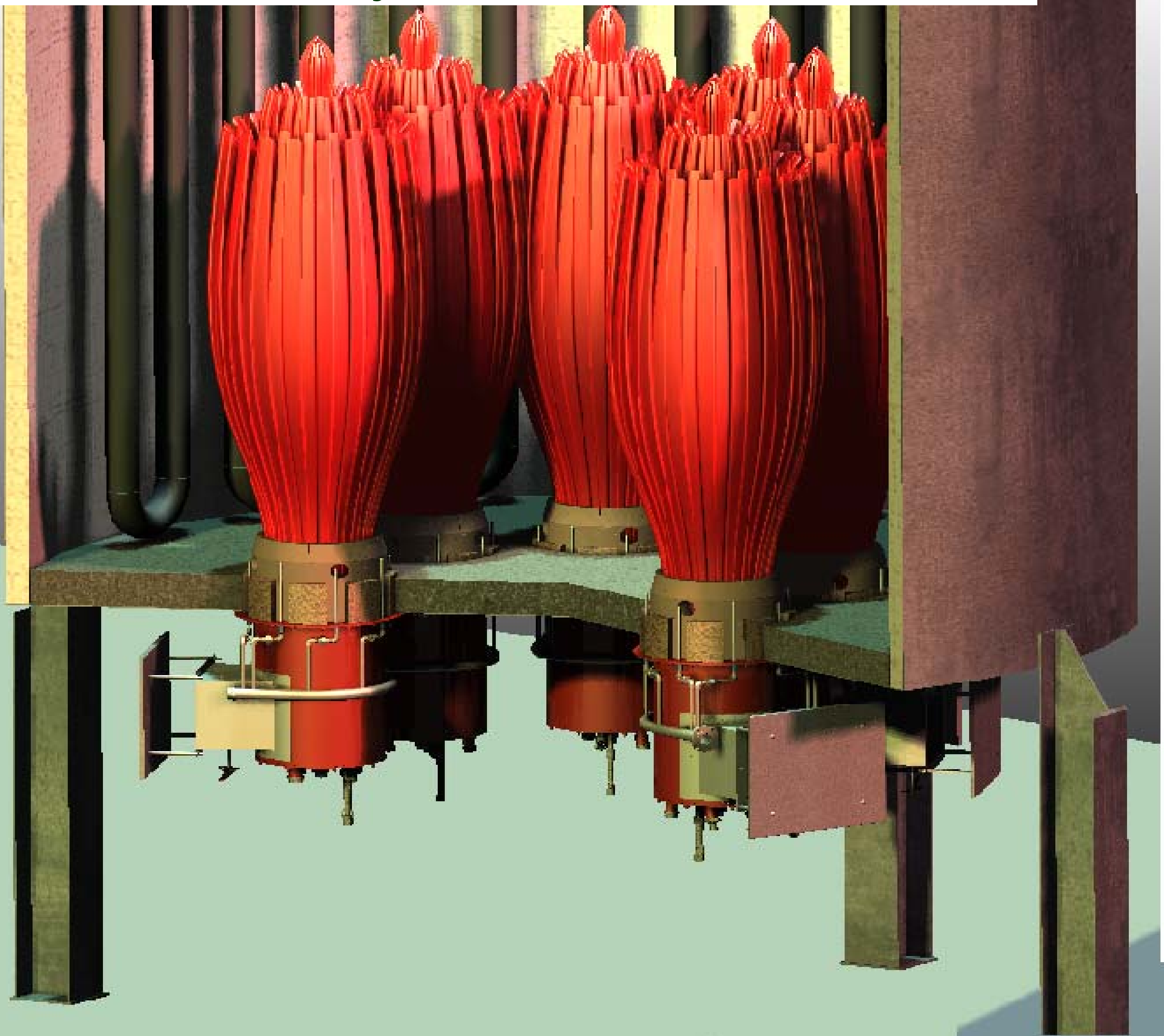


Keys to a Successful Next Generation Low NO_X Burner Retrofit Project

- An Ideal Burner Retrofit Is Transparent to Operations.
- Fits the Right Level of Technology to the Furnace.
- Does Not Affect Process Efficiency or Capacity.
- A Burner Retrofit Can Be Part of a Capacity Expansion, De-bottlenecking, Capacity Expansion or Efficiency Improvement Project.

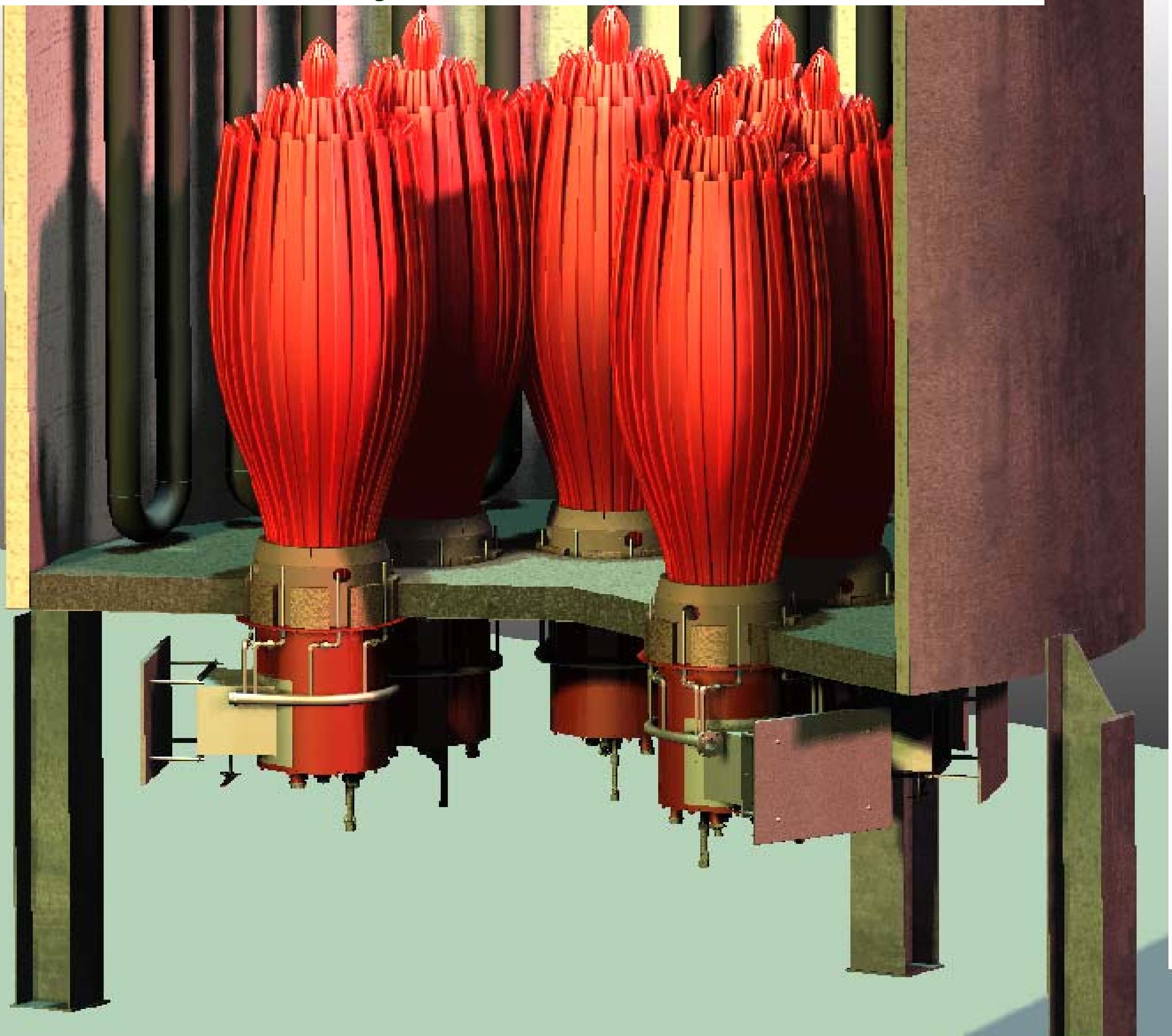
Keys to a Successful Next Generation Low NO_X Burner Retrofit Project

- Confirm Heater Nameplate Capacity Matches Reality
- Consider Heater Volume and Burner Spacing
- 400,000 Btu / Hr / Ft2
- 15,000 Btu / Hr / Ft3
- Computation Fluid Dynamic (CFD) Modeling



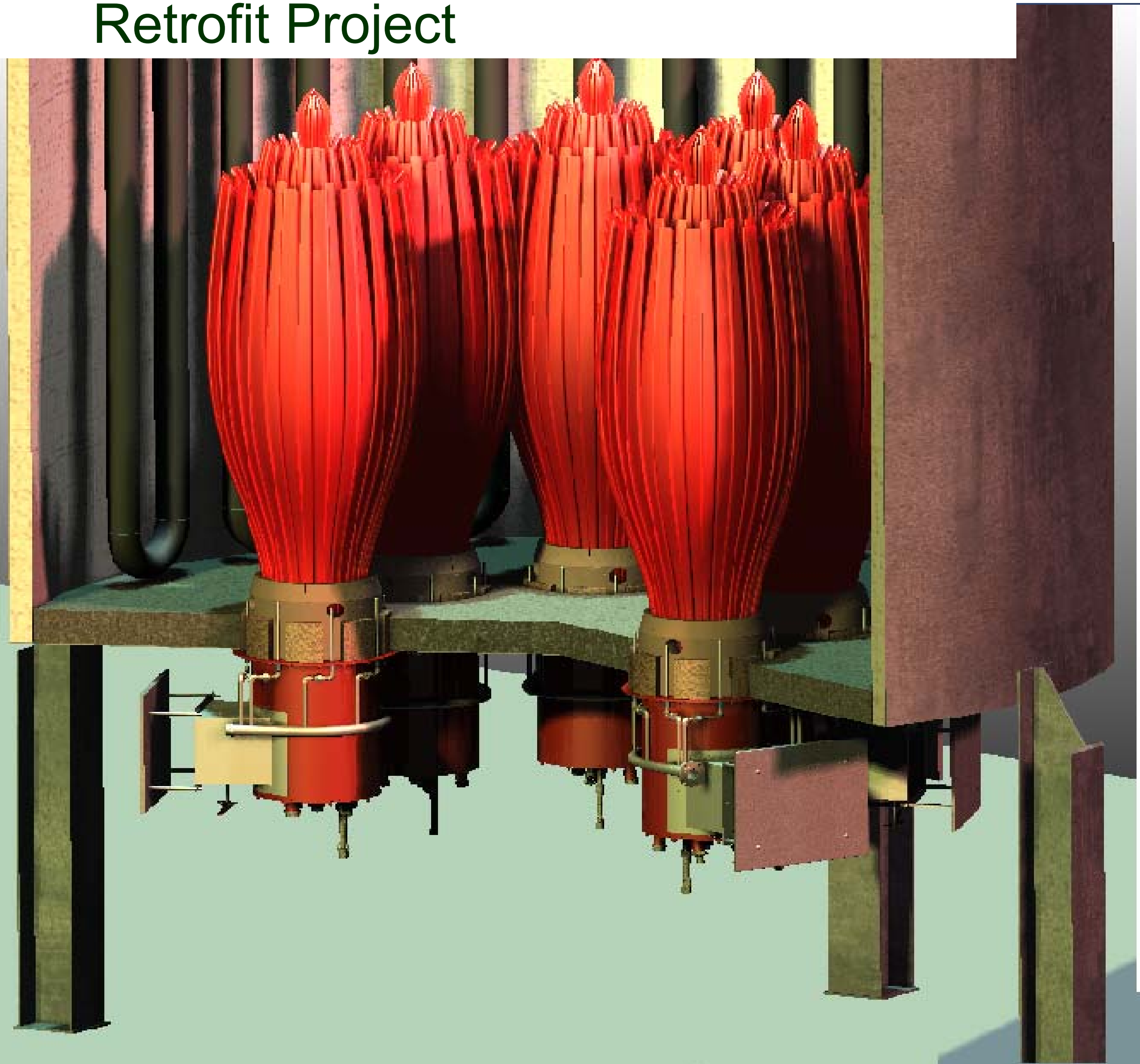
Keys to a Successful Next Generation Low NO_X Burner Retrofit Project

- Seal Heaters to Eliminate “Tramp” Air in the Radiant and Convection Sections
  - Emissions, Efficiency, Controllability
- Ensure All Air Control Systems and Devices Are in Good Working Order
  - Stack Dampers, Air Registers, Fan Controls and Air Preheaters
  - Automate Air Control Wherever Possible



Keys to a Successful Next Generation Low NO_X Burner Retrofit Project

- Establish a Clean, Dry Fuel Source
  - Small Gas Ports, Existing Debris in Pipe
- Confirm Burner Performance in Test Furnace and Field
- Partnership to Develop Technologies for Difficult Applications



Low NO_X Burner Technologies

- Fuel or Air Staging
- Internal Flue Gas Recirculation
- Steam Injection or Other Inert Gas Injection
- Lean Premix
  - Thorough Mixing of Fuel and Air
  - Keeps Combustion Lean at All Times
  - First Practical Patent Granted in 1995
  - Joint Development, Exxon, Callidus, GRI & TIAX (ADL)
- Advanced Combination of These Technologies is termed "Next Generation Low NO_X"

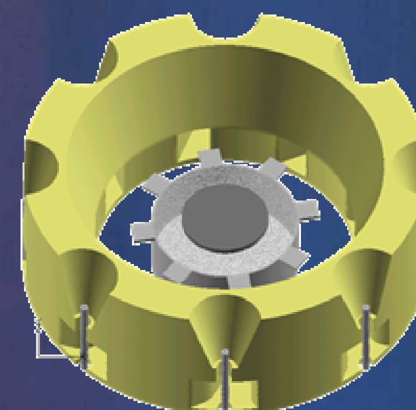
ExxonMobil

TIAX Powered by Innovation

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA ·

Next Generation Low NO_X Burners

- <u>**The Burners Installed in California in 2002 Are Much More Advanced Than Those Installed in 1991.**</u>
- <u>**The Burners Installed in Texas in 2007 Will Be Much More Advanced Than Those We Installed in 2002.**</u>



- <u>**We Continuously Advance Burner Technology**</u>
- <u>**Partnerships With End Users Links Them to The Latest Technology**</u>

Next Generation Low NO_X Burners

- What They <u>ARE</u>
  - **Advanced Applications and Combinations of Existing Technologies**
  - **Flame Is Rooted to Burner**
  - **Continuous, Connected, Well Defined Flame Pattern**
  - **Fuel and Air Are Deliberately Mixed Together**

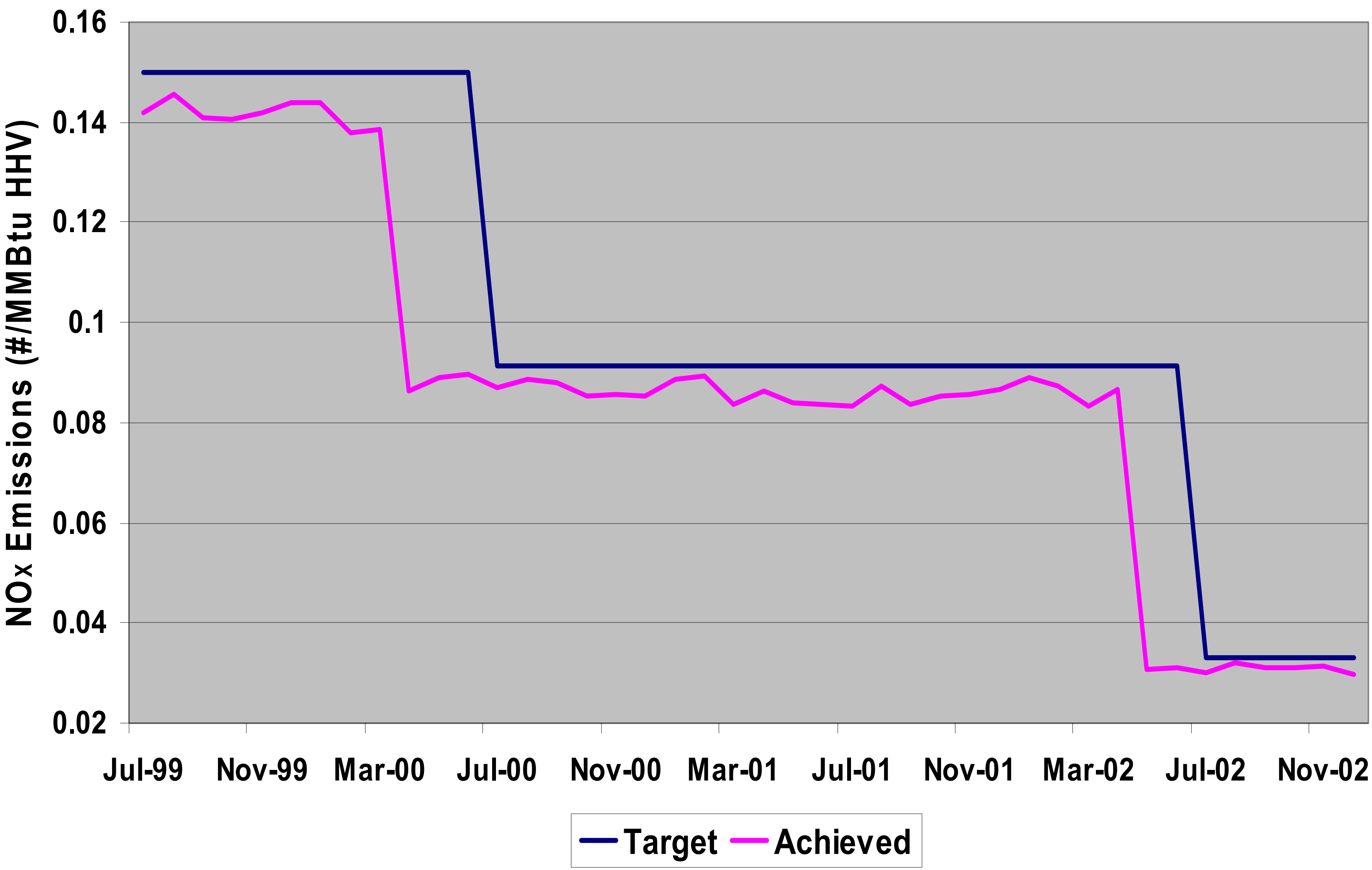
<u>SEEING IS BELIEVING !</u>

- What They <u>ARE NOT</u>
  - **Tube Stabilized Combustion: Boundless, Undefined Flame**
  - **Highly Sensitive to Furnace Geometry**
  - **Test Furnace and Field Results Cannot Be Correlated**
  - **Deep Fuel and Air Staging**
  - **Fuel Incineration**
  - **Invisible Flame is Uncontrolled Flame**

SAMPLE EVALUATION OF RETROFIT COST PER POUND OF NOX REDUCED

Heater No.	Option Description	Estimated Cost	Baseline Duty	Baseline NOx	Baseline NOx	Future Design Duty	Future Design NOx	Future Design NOx	Baseline-Normal Delta NOx	NOx Reduction Cost
		$M	MMBtu/hr	lb/MMBtu	lb/hr	MMBtu/hr	lb/MMBtu	lb/hr	lb/hr	$M/lb/hr
A	New LNB	$1,000	16.6	0.168	2.78	40	0.032	1.28	0.51	$441
B	New LNB	$700	15.8	0.125	1.97	20	0.03	0.6	0.47	$467
C	New LNB	$700	8.3	0.122	1.02	31	0.03	0.92	0.25	$913
D	New SCR	$7,500	91.2	0.109	9.94	239	0.012	2.87	1.04	$842
E	New LNB	$7,900	135	0.333	44.96	175	0.04	7	144.67	$55
E	New LNB & New SCR	$3,500	135	0.333	44.96	175	0.012	2.1	43.34	$81

Northern California Refinery NO_X Reduction Plan



Key Lessons Learned from Northern California Experience

- Plan! Organize Around That Plan
- Pick Strategies That Packs the Most Bang for the Buck
- Establish Measurable Specifications and Goals
  - Post Progress Toward Goals for All to See
- Select Technology Mix to Meet Your Needs
  - Develop Specific New Technologies When Needed
- Join in Performance Testing of New Technologies
  - Demand and Specify Exhaustive Testing Then Verify in Field
- Front Load Projects With Riskier Applications